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COAL-RESEARCH ACTIVITIES OF THE BUREAU OF MINES

BY

ARNO C. FIELDNER

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

COAL-RESEARCH ACTIVITIES OF THE BUREAU OF MINES[1]

By Arno C. Fieldner[2]

OBJECTIVES AND SCOPE OF RESEARCH ACTIVITIES

The objectives of the coal-research activities of the Bureau of Mines are very well expressed in the organic act of Congress establishing the Bureau. It reads as follows:

> That it shall be the province and duty of the Bureau of Mines, subject to the approval of the Secretary of the Interior, to conduct inquiries and scientific and technologic investigations concerning mining, and the preparation, treatment and utilization of mineral substances with a view to improving health conditions, and increasing safety, efficiency, economic development, and conserving resources, through the prevention of waste in the mining, quarrying, metallurgical and other mineral industries; to investigate explosives and peat; and on behalf of the Government to investigate the mineral fuels and unfinished mineral products belonging to, or for the use of, the United States, with a view to their more efficient mining, preparation, treatment, and use; and to disseminate information concerning these subjects in such a manner as will best carry out the purposes of this Act.

This broad enabling act covers all kinds of mineral fuels and their derivatives. The keynote of the objective is conservation - conservation of the lives and health of the workers in the mineral industries and conservation of mineral fuel resources through reduction of waste and more efficient utilization. The public interest is paramount in the activities of the Bureau, which maintains an independent position with reference to conflicting commercial interests. An important part of the research program is directed toward obtaining fundamental facts on the chemical and physical properties of the coal resources of the United States, covering the entire range from peat to anthracite. Such data are broadly useful to both Government and industry. They are required in virtually all applied research and engineering investigations on the mining, preparation, processing, and utilization of coal. The Bureau's own research program in these fields of endeavor is largely planned along fundamental and long-range lines that may not be particularly attractive to commercially supported agencies. In general, the following projects represent research activities of the type that has been favored in Bureau of Mines programs:

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote is used: "Reprinted from Bureau of Mines Information Circular 7367." Presented at Annual Meeting of American By-Product Coke Institute, Absecon, N. J., June 17, 1946.

2/ Chief, Fuels and Explosives Branch, Bureau of Mines, Washington, D. C.

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1. The determination and publication of the chemical and physical properties of American coals, including tests for assessing their suitability for various uses, such as combustion, carbonization, gasification, liquefaction, and the yield of chemical products.

2. The development and standardization, in cooperation with other agencies, of methods of sampling, analysis, and testing.

3. Conducting research and making tests relating to coal belonging to or for the use of the Government.

4. The study of mining methods with a view to improving the safety of workers and increasing the recovery of coal.

5. Improvement of coal preparation and reduction of coal lost in the refuse.

6. Prevention of gas and dust explosions in coal mines.

7. Reduction of stream pollution from mine water and of waste waters from washeries and coal-processing plants through the development of practical methods for minimizing these wastes without imposing onerous costs on the industry.

8. Improvement in the smokeless combustion of bituminous coal and in the processes for producing smokeless fuel from bituminous coal.

Activities in these projects have varied from time to time, in accordance with the personnel and funds available, but some work is in progress at present in most of them, as I will show in this paper.

LOCATION OF LABORATORIES AND PILOT PLANTS

Research and testing relating to coal are conducted at six laboratories in different parts of the country; however, the staff and work at the Central Experiment Station at Pittsburgh, and Bruceton, Pa., are more than the sum of the other five laboratories. Research on coal preparation and other problems peculiar to areas other than the central region of the United States is in progress at the Northwest Experiment Station, Seattle, Wash.; the Southern Experiment Station, Tuscaloosa, Ala.; and the subbituminous coal and lignite laboratories at Golden, Colo., and at Grand Forks, N. Dak.. The most recent laboratory to be established is the synthesis-gas-research laboratory at Morgantown, W. Va., which is designed to study processes for making hydrogen and carbon monoxide from coal in connection with synthetic liquid-fuel processes. In 1942 Congress authorized an anthracite research laboratory in the Pennsylvania anthracite region, and the Bureau of the Budget has sent to Congress this year an estimate for an appropriation of $450,000 for constructing and equipping this laboratory in the fiscal year ending June 30, 1947. The laboratory will investigate the mining, preparation, and utilization of anthracite, attempt to develop new uses and markets, and seek to improve health and safety conditions in the anthracite industry.

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FIELD RESEARCH

Not all of the Bureau's research and technologic activities are restricted to its laboratories and experiment stations. Much of this work, especially in the mining and preparation of coal, is conducted in the mines and preparation plants in cooperation with coal operators. The experiment stations, laboratories, and field offices of the Bureau serve as headquarters for this field work. To a lesser degree field work is pursued in combustion, carbonization, and gasification research in commercial plants. Field investigations during the war are examplified by the coke-production survey, with which members of the By-Product Coke Institute are familiar. This survey was undertaken to maintain the output of pig iron at the maximum production capacity of existing blast furnaces by improving the quality and increasing the quantity of metallurgical-coke production. The survey was made by members of the Bureau of Mines staff, with the advice of a committee consisting of leading coke-oven and blast-furnace engineers and representatives of the Solid Fuels Administration for War, the War Production Board, and the Bureau of Mines. The prompt publication of information collected at various coke-oven plants on innovations and improvements for increasing output and quality of blast-furnace coke aided greatly in meeting the increased demands for pig iron.

In a similar manner, during the last 2 years of the war the Bureau carried on a Nation-wide fuel-conservation campaign enlisting the aid of thousands of volunteer engineers and fuel users, to prevent a serious shortage of coal due to declining manpower and wearing-out of equipment in the mines. It is conservatively estimated that at least 5 million tons of coal were saved during the coal year ended March 30, 1945. Both surveys involved numerous analyses and tests of samples taken at plants, and they brought the Bureau's attention to important research problems, of which some were completed during the war and others remain to be continued under peacetime conditions.

CURRENT RESEARCH ACTIVITIES

Reconversion to postwar problems and a peacetime economy is the keynote of the 1946 program of research and technologic investigations of the Bureau of Mines relating to coal and its products. During the past 4 years nearly all work was directed toward winning the war. These activities ranged from exploration of new coal deposits to ultimate utilization of coal and coal products. Close cooperation was maintained with the Solid Fuels Administration for War in providing technical and engineering services required by that agency in maintaining adequate standards of quality in mining and preparing coal and in producing metallurgical coke. Advice was given to Government and commercial consumers on the safe storage of coal so that large stock piles could be built up during slack periods of fuel consumption, and engineering services were provided on the selection of available substitute fuels in plants where the supply of the fuel normally used became inadequate. Laboratory and pilot-plant studies of the coking properties of midcontinent and western coals, made by the Bureau and by industry, furnished data for selecting the most suitable coals available for production of metallurgical coke for new blast furnaces in Texas, Utah, and California.

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The postwar program must include a return to the normal peacetime objectives of research and technologic work on wise conservation of the Nation's coal resources by making progress in safer, more efficient methods of mining, preparation, and utilization of coal and lignite. However, our war experience has in many instances changed the emphasis to new problems and possibilities resulting from new developments in the application of chemistry, physics, and engineering to the production of different forms of fuel. A considerable increase may be expected in the variety of chemical products that may be produced from coal, petroleum, and natural gas. New forms of equipment for mining and preparation of coal will result from a substantial increase of research activities in the next few years. A probable decline in discovery of prolific new pools of petroleum in the United States may lead to an important synthetic liquid-fuels industry in the next two decades. Development of a relatively cheap process for making synthetic liquid fuels from natural gas, costing not more than 5 cents per thousand cubic feet, may render it uneconomical to build new long-distance pipelines for transporting such gas from Texas to the industrial East. If the cost of oxygen production can be lowered materially, it may be possible to gasify coal completely with the aid of oxygen. Such gas made in the Appalachian coal field could be blended with natural gas to increase the supply. Industrial research is in progress in this country on the gasification of powdered coal, and the Russian experiments on underground gasification are creating enough interest so that experiments may be started in the United States.

Shortly before the beginning of the war, the city of St. Louis, Mo., passed an ordinance enforcing rather strong measures for attaining smoke abatement. The burning of high-volatile bituminous coal was permitted in domestic furnaces only when provided with mechanical stokers which operate with virtually smokeless combustion. In the absence of such stokers, the permitted fuel was limited to gas, oil, coke, anthracite, and low-volatile coal. It is probable that, in the postwar period, other cities will follow this example and thus compel the coking of coal at high or low temperatures to provide smokeless solid fuels for those who cannot install mechanical stokers. An incentive will thus be provided for expanding the coal-processing industry in many communities. Research and development work is needed to provide satisfactory equipment for this purpose. These are some of the indications that point toward new horizons of coal research.

It was my original intention to confine my paper to Bureau of Mines activities directly related to the coking industry; however, in attempting to draw a distinction between related and nonrelated work, I found it difficult to find a sharp dividing line. I therefore took the easy course and decided to present a brief résumé of all the current research and technologic work relating to coal, coke, and other coal products. This will be presented under the following headings:

1. Properties of coal.
2. Mining
3. Preparation and storage.
4. Combustion.
5. Carbonization and gasification.
6. Liquefaction.

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Properties of Coal

One of the earliest activities of the Bureau of Mines was to survey the composition of American coals, as determined from standard samples taken at the face of the coal bed in the mine and also from standard samples of the different sizes of coal as shipped from the tipple. Many of these samples were taken by Bureau engineers while inspecting coal offered by bidders on Government contracts. Other samples were taken in connection with investigation of the Nation's coal reserves by the Federal Geological Survey. This is being continued at present. The gross samples, taken in a uniform, representative manner, are crushed mechanically at the mine with the aid of a special sampling truck and reduced to a size suitable for shipment, in moisture-tight containers, to the coal-analysis laboratory at the Pittsburgh Experiment Station. Proximate and ultimate analyses, calorific values, and ash-fusion temperatures are determined on most of these samples; and in special cases agglomerating, weathering, caking, grindability, and friability tests are made. The results of these tests are published from time to time in a series of technical papers, one for each of the coal-producing States. The data are grouped alphabetically according to the counties in the State, and under the counties the analyses are arranged alphabetically according to the town nearest the mine from which the sample was taken. This basic information is available not only to other Government agencies but to industry as a guide in selecting coals best-suited for combustion in various types of equipment; for the production of metallurgical coke, gas, and byproducts; for the complete gasification of coal; and for the manufacture of synthetic liquid fuels.

One of the fundamental methods of studying the origin and constitution of coal is examination of its structure as shown in thin sections or in polished and etched surfaces viewed under the microscope. The late Dr. Reinhardt Thiessen, of the Bureau of Mines, was one of the pioneering investigators in this field of research. His publications have shown the paleobotanical structure of the various types of American coals. His work is being continued by other investigators in the Bureau laboratory at Pittsburgh. A systematic microscopic examination and petrographic analysis of vertical sections of coal beds from which samples of coal were taken for carbonization studies have been helpful in explaining variations in the coking properties of coals that were not evident from the chemical analyses. In some instances such examination pointed the way toward material improvement of the quality of the coke by rejecting a certain bench of the coal bed.

A more specific application of petrographic analysis was found in estimating the amenability of a coal to hydrogenation and liquefaction by the Bergius process. Examination of a number of samples indicated close relationship between the sum of the percentages of opaque attritus and fusain and the percentage of unliquefiable residue on hydrogenation.

Petrographic examination of coals also has been especially useful in the geological correlation of coal beds. Recently, Dr. James Schopf, paleobotanist of the Bureau laboratory at Pittsburgh, has developed a new maceration process in which plant fossil structures, such as spores, can be separated and identified, thus affording means for recognizing the characteristics of different coal beds. Schopf also has developed a method for

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eliminating the tedious process of making numerous thin sections of the different benches of coal from the top to the bottom of a column representing a coal bed in order to obtain a representative petrographic analysis. He has succeeded in making a dense cylindrical pellet by compressing a representative sample of finely pulverized coal at very high pressures and then making a thin section of this pellet for microscopic examination. A quantitative determination of the percentages of fusain and translucent and opaque matter can readily be made by measuring the respective areas occupied by these constituents. These two new procedures will facilitate further research in coal petrology.

Among the most important properties of coals, from the standpoint of the coke-oven operator, are their plastic and swelling characteristics on heating. When a coking coal is heated at a moderate rate in the absence of air it gradually softens, coalesces, and swells, giving off gases and vapors; it then hardens to form a cellular structure in the case of coking coals. Different coals show marked distinctions in the degree to which these plastic and swelling characteristics are shown, and even for the same coal the magnitude of these changes is affected greatly by the particular conditions under which such properties are determined. The transient nature of the plastic state of coal makes it especially difficult to measure the consistency of the partly fused mass and the temperatures of this plastic range. Many investigators have investigated the phenomena attending the plastic state of coal and have developed procedures and apparatus by which some of these properties may be measured approximately. J. D. Davis, R. E. Brewer, and associates in the Bureau of Mines have made comprehensive studies of the various proposed methods and have compared the results obtained with the different types of instruments for measuring plasticity with the coking properties of coals as determined in the BM-AGA carbonization test. The results of this investigation, together with a review of the literature, was published by Brewer[3/] in 1942. It was found that the various kinds of apparatus used by different investigators could be classified in three general types according to the principles on which they are based. These are: (1) Penetrometer or shearing instruments, in which the resistance of a needle moving vertically or laterally through the plastic coal mass, or the resistance of a stirring device within the mass, is measured as the mass is heated and the temperature observed; (2) dilatometer methods, in which the linear expansion or contraction of a test sample of coal is measured while being heated at a definite rate through the plastic range; and (3) gas-flow methods, which depend on measuring the changes in the resistance to flow of a current of nitrogen offered by a bed of granular coal as the void spaces of the test sample change on account of coalescence of the coal as it passes through the plastic stage. The Bureau of Mines selected at least one of each type of test for use in its survey of the carbonizing properties of American coals. These were (1) the Davis and the Gieseler plastometers which measure the resistance to turning of a stirrer offered by the plastic coal; (2) a

3/ Brewer, R. E., Plastic and Swelling Properties of Bituminous Coking Coals: Bureau of Mines Bull. 445, 1942, 260 pp. (Price 30 cents, obtainable from Supt. of Documents, Washington, D. C.)

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combination of the Agde and Damm dilatometer tests; and (3) a modification of the Layng-Hathorne version of the Foxwell gas-flow test. With these methods of test, the following approximate points may be measured in the range of temperatures in which a coal softens, swells, and hardens to form coke:

(1) Initial softening or contraction temperature.

(2) Initial expansion or swelling temperature.

(3) Temperature of maximum plasticity or maximum fluidity.

(4) Final solidification temperature.

The relative plasticity or consistency of the liquid-solid mixture at various temperatures is expressed by the torque in inch-pounds indicated by the Davis plastometer and by the divisions per minute pointer movement of the Gieseler apparatus.

A study of the large amount of information obtained in the use of these instruments indicated that the Davis and the Gieseler plastometers gave the most useful data on the evaluation of coals with respect to their coking properties and their plastic or swelling behavior on stokers in coal-burning furnaces. In both methods the resistance to shear of a heated charge of coal is measured. In the Gieseler instrument the consistency is determined by measuring the rate of rotation of a stirring shaft in the coal as it is being heated through the plastic range. A constant force is applied to the stirring shaft, and the rate of rotation is observed by reading the movement of a pointer over a graduated dial. In the Davis instrument the coal charge as a whole is rotated and stirred; the property measured is the resistance to shear of the partly fused coal adhering to the periphery of the retort. The resistance is created by the movement of the coal in the retort against rabble or stirring arms on an inside shaft, which is prevented from free rotation by a set of tension springs. With increase in the fluidity of the heated coal a decrease in the resistance or torque is noted. Both methods have been investigated further by Committee D-5 on Coal and Coke of the American Society for Testing Materials, and it is expected that one or both will be recommended as tentative standards at the coming June meeting of the society. Such standardization will facilitate their practical use by the coking industry. At present it appears that they will be helpful (a) in proportioning blends of coals to secure coke of optimum physical properties and avoiding expansion characteristics detrimental to oven structure; and (b) in determining the effect of oxidation of coal incident to storage on the coking properties of the coal. These tests also promise to be useful in assessing the caking tendencies of coals in stokers, especially those of the underfeed type, and in gas producers and water-gas machines.

The practical importance of avoiding the use of coals or mixtures of coals that have expansion characteristics that damage the coke-oven structure has led to the development of a number of different tests in which either the expansion of a charge of coal is measured while heated under constant pressure

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through the coking range of temperatures or the pressure developed is measured while the charge is heated at constant volume. The size of charge used in the different methods varies from a few ounces to several hundred pounds; and it usually has a rectangular form similar to a coke oven, although it may be in a horizontal position heated from one side only or in a vertical position heated from one or from both sides. In common with several other laboratories, the Bureau of Mines has studied several of these methods and has published a number of papers on expansion methods and the expansion properties of a number of American coals and blends of coals. The Coal Carbonization Laboratory at the Bureau's Pittsburgh Station has the following three expansion-testing ovens:

(1) A sole-heated oven. 40 pounds coal capacity; constant pressure of 2.2 pounds per square inch; movable top.

(2) A small vertical-slot oven; heated on both sides; 17 pounds coal capacity; movable wall; constant pressure or constant volume.

(3) A large vertical-slot oven; heated on both sides; 200 pounds coal capacity; movable wall; constant volume.

Active cooperation is in progress with the A.S.T.M. Committee D-5 on Coal and Coke in a study of the relation of expansion tests made with these ovens and practical experience obtained in the use of the same coals in commercial ovens. Whichever one of these ovens is adopted as standard by the A.S.T.M., it must fulfill the requirement of measuring the expanding properties of a coal which is defined by the subcommittee as follows: "Expansion is the property of certain coals to change in volume when carbonized, with restraining influence, as in a coke oven." "Free swelling" is defined by the same subcommittee in the following words: "Free swelling is the property of certain coals when heated, without restraining influence, to expand freely in volume, as in the volatile-matter test or when burned as a fuel." A simple crucible method for the free-swelling test has been recommended by the subcommittee and probably will be adopted as a tentative standard by the A.S.T.M. at the coming annual meeting the latter part of June. Although the "free-swelling test" is designed for the use of fuel engineers in examining coals for use in stokers and gas producers, it also is useful to coke-oven superintendents in detecting weathered strip coal or coal that has lost much of its coking property on account of oxidation in storage.

Coal is an exceedingly complex and variable substance. I could go on for hours and discuss with you its properties and their influence on its use. Much of our Bureau program is directed along these lines. I have pointed out a few of the more important ones and will proceed to the Bureau's work on exploration, mining, and preparation of coal.

Mining of Coal

A major portion of the Bureau of Mines appropriations is expanded for improving health and safety conditions of workers in the coal-mining industry. Research along these lines is conducted principally at the Central Experiment

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Station, Pittsburgh, Pa., and at the Experimental coal mine and Explosives Testing Station, both at Bruceton, Pa. (near Pittsburgh). Mining explosives, mine lamps, gas detectors, gas masks, dust respirators, oxygen breathing apparatus, and various electrical equipment for use in coal mines may be submitted by the manufacturers for safety tests by the Bureau of Mines. If the explosive or equipment passes the Bureau's requirement, the manufacturer is given a certificate of permissibility stating that it is safe for use in coal mines. Examination of new devices, new equipment, and new explosives requires much research in cooperation with the manufacturer in perfecting the apparatus or material so that it will pass the required permissibility tests. Considerable research is now in progress on new compositions suggested for mining explosives by developments in military explosives during the war. In the Experimental mine, research is being conducted on the relation between the amount of permissible explosive fired in a single charge and the danger of igniting a mixture of methane and air at the face where the shot is fired. This information is important because of the tendency to use larger charges of explosives with the increase of mechanization in mining. A study of methods of loading and stemming the charge has shown that these have considerable influence on the prevention of ignition of gas or dust and that with certain precautions larger charges than the present limit of 1½ pounds of explosive per charge may be used safely.

During the war Bureau engineers supervised exploration of coal deposits to determine the extent of minable reserves of coal in areas where there was shortage of supply, as in Alaska, Washington, and Oregon; and also where coking coals were needed, as in Utah, New Mexico, and Colorado, to supply the new blast furnaces at Geneva, Utah, and at Fontana, Calif. Exploration projects in western Colorado, the Georges Creek field in Maryland, and the Coosa field of Alabama are now in progress.

In the Pennsylvania anthracite region two important mining studies started in 1945 are in progress. These consist of working out a plan to prevent the flooding of anthracite mines and the development of better machines for mining pitching beds. John Buch of the Bureau's staff spent several months in the Ruhr district of Germany and other European and British mines studying their methods. An Eickhoff shearing machine has been obtained from the Ruhr for trial in pitching beds and a German coal planer will be constructed and tested.

Preparation of Coal

Harry F. Yancey and Thomas Fraser, coal-preparation engineers of the Bureau of Mines, studied new developments in coal preparation in Great Britain and western Europe in 1945. This year they will maintain close contact with American coal operators and acquaint them with what they have learned abroad. Up to the present, the Bureau has had no coal-preparation laboratory at the Central Experiment Station at Pittsburgh, Pa. The need for one in this region will be filled during 1946 by installation of a modern coal-preparation laboratory in connection with the research and development laboratories synthetic liquid fuels being constructed at the Experimental coal mine, Bruceton. Superpreparation processes are required to produce ultra-low-ash coals for the hydrogenation method of making liquid fuels

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from coal. Thomas Fraser is in charge of this project, and he will keep in touch with industrial coal preparation in the anthracite, northern Appalachian, and midcontinent regions.

At the Northwest Experiment Station, Seattle, Wash., H. F. Yancey has added to his excellent equipment an electrostatic cleaning machine for fine coal, a Vissac jig, and a Driessen cyclone cleaner. At the Southern Experiment Station, Tuscaloosa, Ala., B. M. Gandrud likewise has a well-equipped laboratory for research on problems of the Southern Appalachian region. A four-cell machine expecially designed for kerosine flotation of coal is being installed.

Combustion of Fuels

Combustion research and fuel economy engineering have been primary functions of the Bureau ever since it was established. In fact, the forerunner of the Bureau was the Fuel-Testing Plant of the Geological Survey, which conducted the first systematic investigation of the properties and utilization of American Coals at the World's Fair, St. Louis, Mo., in 1904. This work now includes research on combustion and fuel-burning equipment and fuel-economy service to Government power and heating plants. Most of the research is conducted at the Pittsburgh Station, and the engineering service is directed from Washington.

Current research relates to the clinkering and slagging actions of coal ash, with special reference to flow characteristics of coal-ash slags on heat-absorbing surfaces of large boiler furnaces. A high-temperature furnace and auxiliary equipment have been constructed for measuring the thermal conductivity of molten slags so that data can be obtained for calculating the rate of heat transmission through layers of slag on boiler tubes. To measure the true viscosity of coal-ash slags under the various oxidizing or reducing conditions that may prevail in furnaces, a specially designed, torsion-type, electrically heated viscosimeter was constructed in which any desired atmosphere could be maintained. Much valuable fundamental information has been obtained with the aid of this apparatus in the study of the mechanism of slag formation and the effect of the chemical composition of the ash and of the oxidizing nature of the atmosphere on the flow of the slag. Viscosity data are useful in the problem of ash removal from slag-tap furnaces in which pulverized coal is burned. It is now possible to predict, for slags of widely different compositions, the relative ease of tapping in a given furnace. The adherence of slag to heat-absorbing surfaces is a major problem of industrial furnaces at high ratings, and information on the flow properties of slags will assist in its solution. When the viscosity conditions existing in fuel beds can be precisely stated, viscosity data will assist also in explaining clinker formation, particularly the "sheet" clinker formed at high ratings. Thus, it is hoped that ultimately, clinkering and slagging problems in the use of fuels under various conditions can be solved. A related problem, recently undertaken in cooperation with the public utility power-plant industry, centers on the corrosive action of slags on water tubes of large steam boilers. Although this action has been observed occasionally to some degree for a period of years, it was not recognized as an acute source of

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boiler "outage" until the war made it necessary to keep boilers continuously in operation at high rates. Excellent progress has been made in identification of the compounds that are formed in the slag and react with the iron of the tubes. The mechanism of this reaction is being unfolded, and means for its prevention are being worked out.

The fuel-economy service to Government agencies provides advice as to specifications and choice of proper fuel and fuel-burning equipment for Government installations and gives consulting engineering services, including tests pertaining to the acceptance and most efficient operation of power and heating equipment. The prevention of scale formation and corrosion by proper feed-water conditioning is an important part of the Bureau service to Government plants. The results of studies made in this service are published for the benefit of industry in general.

The National Fuel Efficiency Program, which was conducted during the war, was instrumental in preparing a series of valuable quiz sheets with the voluntary aid of leading fuel engineers of the coal producing and consuming industry. During the present year it is planned to issue these sheets in bulletin form so that they can be used by fireman and engineers to obtain the maximum efficiency of fuel-burning equipment and to keep down fuel and heat losses. Special attention also will be given to developing adequate municipal codes for smoke abatement and improvement of equipment for smokeless combustion of high-volatile coal in small heating and power plants.

Carbonization and Gasification of Coal

Next to the direct use of coal as fuel, the manufacture of gas and coke with the attendant byproducts is the most important utilization of coal. The selection of coals for these processes and their intelligent control require not only proximate and ultimate analyses, but numerous other tests as well, as has been shown in the discussion of the properties of coal in the forepart of this paper. From time to time, technologists have devised small-scale gasification or coking tests on coal samples ranging from a few ounces to several pounds. Some of these tests yielded useful data when interpreted in the light of experience with similar coals used in the same plant equipment. But tests with such small quantities do not provide sufficient amounts of carbonization products to permit their quality as well as their quantitative yield to be determined. For these reasons and others, a committee of the American Gas Association in 1927 asked the Bureau of Mines to develop a suitable standard assay test for the gas-, coke-, and byproduct-making properties of coals and to apply this test in a survey of American coals.

The test as finally developed consists of carbonizing a charge of 175 to 200 pounds of crushed coal in a cylindrical steel retort 18 inches in diameter and 26 inches in height. The charged retort is welded gastight and placed in an electrically heated furnace which has previously been brought to the desired temperature of carbonization and then is automatically maintained at this temperature until gas evolution ceases. The volatile products are recovered by passing them through a suitable condensing, scrubbing, and byproduct-recovery train. The gas is metered, and continuous determinations are made of its specific gravity and calorific value. To obtain comprehensive

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data for both high- and low-temperature carbonization, tests are made on different charges of the same uniform lot of coal at a series of temperatures varying in 100° C. intervals ranging from 500° to 1,000° C. The yields of all products are measured, and their physical and chemical properties are determined.

More than a hundred coals and mixtures of coals have been tested by this method. The results have been published in a series of technical papers, which have made available carbonization data that proved of particular value during the war period in finding new sources of coking coal to supply the increased demand. It was fortunate that the Arkansas and Oklahoma coals had been investigated by the BM-AGA procedure when the need arose for selecting coals for the new coke-oven plants constructed in Texas.

It is not claimed that the results obtained in this assay method approximate in every respect those attained in commercial plants. The yield and quality of the gas, coke, and byproducts are conditioned by the temperature of carbonization, the rate of heating, the charging density, and the temperature and time of exposure of the volatile matter before it is cooled to a point where no further reactions take place. The effect of these factors varies with operating conditions and oven or retort design. However, with intelligent interpretation, this work gives valuable fundamental information for the coal-processing industry. The weakest point in this assay test, from the point of view of the coke-oven operator, lies in comparison of the physical properties of the coke with that obtained in commercial coke ovens. The cylindrical retort gives a different system of fracturing and smaller sizes of coke from that obtained when the flow of heating is the same as that of the rectangular byproduct oven.

For coke studies, a small rectangular, oven 12 to 14 inches in width, about 4 feet long, and 4 feet high gives a better reproduction of the physical properties of commercial oven coke. Experimental ovens of this type have been installed at the Pittsburgh, Pa., Golden, Colo., and Tuscaloosa, Ala., stations. These will be used for a study of the effect of blending, sizing, charge density, oxidation, and other factors on the physical properties of the coke. Special attention will be given to expanding the potential reserve of coking coals of the country by utilizing as far as possible the poorly coking coals as blending constituents with strongly coking coals.

Several years ago Congress directed the Bureau of Mines to investigate methods for gasifying or carbonizing subbituminous coals and lignites, of which very large reserves exist in certain Western States, in Texas, and in the Dakotas. A laboratory for this purpose was established at the Colorado School of Mines, Golden, Colo., and certain of this work was undertaken at the University of North Dakota at Grand Forks, N. Dak. A small, vertical, annular steel retort was developed at Golden, which showed promise for the essentially complete gasification of these noncaking fuels. A year ago a single unit of commercial size was constructed at Grand Forks, N. Dak. This equipment is now in experimental operation. By the introduction of steam, a high-hydrogen water gas containing some methane is obtained. By suitable operation the ratio of hydrogen to carbon monoxide can be varied from about

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2:1 to 10:1. The method has good possibilities for the production of commercial hydrogen or synthesis gas for the Fischer-Tropsch process of making synthetic liquid fuels. This investigation will be continued during the next fiscal year.

Synthetic Liquid Fuels from Coal and Lignite

In 1944 Congress authorized appropriations aggregating $30,000,000 for construction and operation of demonstration plants for production of synthetic liquid fuels from coal, oil shale, and other substances. The first appropriations for this work became available in July 1944. A research and development laboratory for work on coal is now under construction on the Bureau's experimental coal-mine property at Bruceton, Pa., where experimental and small pilot-plant work will be done on coal-hydrogenation and gas-synthesis processes. Commercial-scale pilot or demonstration plants for these two processes will be installed at the Government-owned synthetic ammonia plant at Louisiana, Mo., which was turned over to the Bureau of Mines last December. A gas-synthesis research laboratory is being organized at the University of West Virginia at Morgantown, where research will be conducted on the use of oxygen in gasifying coal and on processes or modifications of processes required to suit physical and chemical properties of various ranks and types of coal.

An oil-shale research and development laboratory is being built at the Bureau's Petroleum Experiment Station at Laramie, Wyo., and an oil-shale demonstration plant and oil-shale mine are under construction at Rifle, Colo., in the oil-shale region of western Colorado.

A number of Bureau of Mines engineers and chemists spent the greater part of the past year in Germany, where they obtained much valuable information on German synthetic liquid-fuel plants and on new developments in mining, preparing, and processing coal. The large synthetic liquid-fuel program of the Bureau, which will be of great value to coal processing in general, will not be limited to the liquid-fuel end product. Much research will be necessary on coal preparation to produce specially low-ash coal and on complete gasification of coal, but the results will be of direct value in the production of industrial fuel gases from coal and lignite. The liquid-fuel program includes comprehensive fundamental research on the chemistry and constitution of coal, which doubtless will be of general value for developing new chemical products from coal and new uses for coal.

CONCLUSION

The foregoing briefly reviews some of the highlights of the part the Bureau of Mines is taking in the rapidly growing program of coal research and technologic investigations being conducted in the United States. It touches a broad field, ranging from the origin of coal to its mining and utilization. The emphasis in the Bureau work is on conservation of our fuel resources by reduction of wastes and by more efficient utilization. And, of course, much of it relates to the improvement of health and safety conditions in the mines and in the mineral fuel industries. The Bureau seeks and is glad to obtain industrial cooperation and it is gratified that the American

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coal industry has become research conscious in a large way. The prospects are bright for a steady growth of industrial research accomplishments that will result from the increasing financial support of such research being given by the producers and consumers of coal.

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